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DIVISION OF FISH AND GAME OF CALIFORNIA

FISH BULLETIN No. 21

Analysis of Boat Catches of White Sea Bass (*Cynoscion nobilis*) at San Pedro, California

By

S. S. WHITEHEAD

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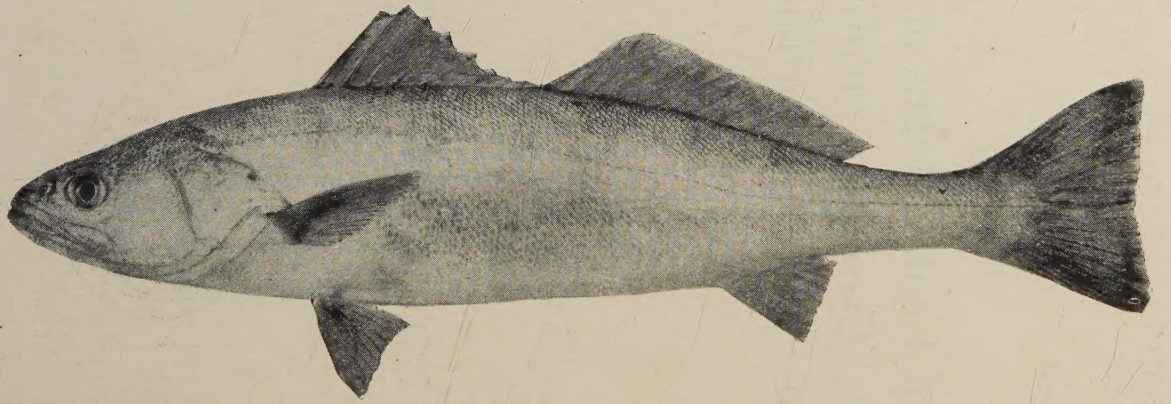

FIG. 1. White sea bass (*Cynoscion nobilis*). These fish may attain a length of four to six feet (50 to 60 pounds).

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ANALYSIS OF BOAT CATCHES OF WHITE SEA BASS (Cynoscion nobilis) AT SAN PEDRO, CALIFORNIA

By S. S. Whitehead

I. INTRODUCTION

Determining the condition of a fishery is a first step in its administration. It is equally as important to learn that a fishery is withstanding a strain as to know that it is being overexploited. If depletion is evident, legislation should be passed to give protection. When the status of a fishery is in question the length of time taken to determine this status is a big factor and the administrator should be advised in the least time possible whether or not protection is necessary. By using the method of determining the return per unit of effort expended as a criterion these needs are met; provided statistics over a long period of years have been collected to give the return per unit of effort.

In California the Bureau of Commercial Fisheries of the Division of Fish and Game has been gathering statistics since 1918 for analyses of its fisheries. By legal requirement the fish buyer records the amount of each species purchased, port of delivery, price, fisherman's name, boat name, boat number, and the date. This record is made out in triplicate in a receipt book issued free of charge by the Division of Fish and Game to all fish buyers. The fisherman's copy is a white receipt, the buyer's yellow, and that of the Division of Fish and Game pink (known as the "pink ticket"). These pink tickets provide the required data for a catch analysis when the catches are the product of one day's fishing. When the catches are the product of more than one day's fishing, the pink tickets are apt to be inadequate because the unit of effort frequently fluctuates. In a fishery where the catches are landed each day, the unit of effort will be one day's fishing, and the amount of fish caught will be the return. As this method of determining increase or decrease of return per unit of effort is a comparison from year to year, it is necessary that the unit of effort remain constant. This means that the gear of the boat as well as the time interval must remain unchanged throughout the period of investigation.

The question as to the condition of the population of white sea bass, *Cynoscion nobilis*, a species of the Croaker family, has been brought to the attention of the Bureau of Commercial Fisheries. As it is the function of the California State Fisheries Laboratory of the Division of Fish and Game to determine the condition of the commercial fisheries of California, the following investigation has been pursued.

The writer wishes to acknowledge his indebtedness to the white sea bass fishermen of San Pedro who furnished the necessary information on fishing methods; to Dr. Frank W. Weymouth of Stanford University; and to the members of the staff of the California State Fisheries Laboratory, who with their constructive criticism, aided greatly in the preparation of this report.

No tables substantiating the graphs have been included in this publication, but these data are on file at the California State Fisheries Laboratory and are accessible to anyone interested.

California State Fisheries Laboratory.

October, 1929.

II. TOTAL CATCH AND AVERAGE BOAT CATCH PER YEAR

A. Total Catch for Los Angeles County.

A presentation of the yearly total catch of white sea bass for Los Angeles County from 1918 to 1928 would be of interest and is produced graphically in figure 2. During this period no legislation was passed restricting the catching of white sea bass. As a result the total catch was not affected by any legislative measures, but was affected by the changes of white sea bass population and the effort expended on the part of the fishermen. Fishing effort is the number of boats engaged in the fishery, amount of gear used, and length of time the gear fishes.

If total catch depended entirely on the population, it would be a dependable index of the condition of the fishery, but fishing effort is too big a factor for total catch to be reliable. For example—the total catch indicated an increase from 1918 to 1919, but in 1918 twenty-two boats fished, while in 1919 forty-eight boats fished. This increase of over 100 per cent helps to explain the increase in total catch. See table 1 for the number of boats (purse seines, lamparas and gill net boats)

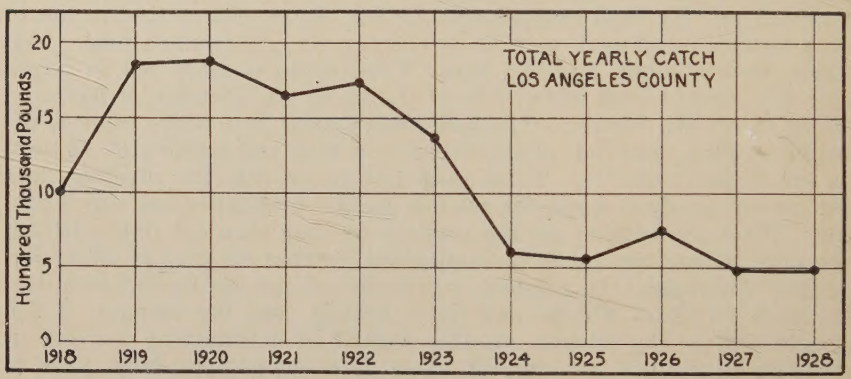

FIG. 2. Annual white sea bass catch in Los Angeles County.

that fished each year. A criterion more accurate than total catch is necessary to indicate the true condition of the fishery.

TABLE 1

	1918	*1919*	*1920*	*1921*	*1922*	*1923*	*1924*	*1925*	*1926*	*1927*	*1928*
No. of boats[a]	22	48	45	63	69	50	34	29	32	26	28

[a] Number of boats that fished white sea bass each year at San Pedro. All boats which made less than seven catches in a year were discarded.

B. Average Boat Catch per Year.

In order to eliminate the error of the change in the number of boats fishing each year the average yearly catch per boat may be used. The light solid line in figure 3 is the trend of the total catch each year divided by the number of boats operating in that year, and the heavy solid line is a smoothing of the averages comprising the light line. Although this trend indicates a decline in the white sea bass fishery, too many factors can hide the true conditions of a fishery when average yearly boat catch calculated in this way is taken as a criterion. For example—a change in the type of fishing boats used from one year to another, or a change in the number of months fished from year to

year may cause a false increase or decrease. The white sea bass fishery may have been depleted to such an extent that any method used will show a decline. In a fishery where depletion is not very pronounced, the inaccuracies of a method such as catch per year may act in such a way as to show a false increase. As a result a more accurate method should be devised in order to be certain that the true conditions of the fishery are shown. To do this, fishing methods and other factors must be studied in order to pick out a method by which a constant unit of effort may be used from year to year.

One source of possible errors in a method using average boat catch per year as an index, when different types of boats are engaged in the fishery, is a change in the type of fishing boats from year to year. An analysis should be from one type of fishing boats to eliminate the mistake of changing the classes of boats. The total catch of the gill net boats (these boats and their gear will be discussed in another part of the report) each year was divided by the number of strictly gill net boats engaged in the fishery, and is shown by the light dotted line of

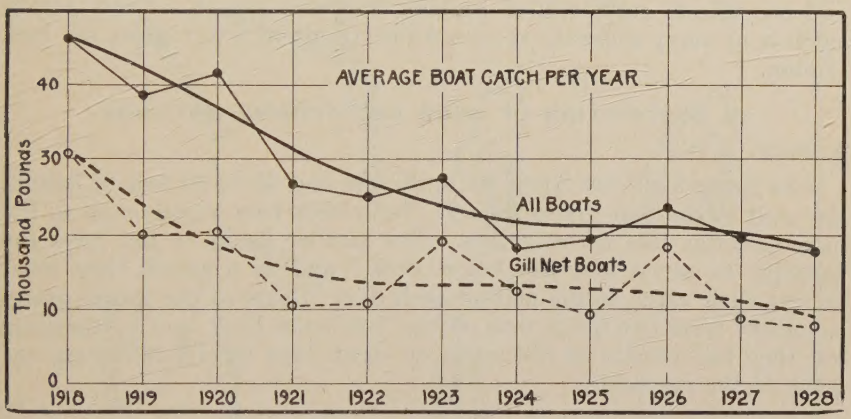

FIG. 3. Light solid line is the trend of the average boat catch per year of all the boats fishing white sea bass in Los Angeles County, and the heavy solid line is a smoothing of the light line. The light dotted line is the trend of the average boat catch per year of the strictly gill net boats, and the heavy broken line is a smoothing of the light dotted line.

figure 3. The heavy dotted line is a smoothing of the averages comprising the light dotted line. This trend differs little from the trend designated by the solid lines except that it is consistently lower. Although the changes in types of boats were eliminated in this method, the source of error due to the possible change from year to year in the number of fishing months is still present. This source of error must be eliminated before a constant unit of effort expended will be certain from year to year.

III. SELECTION OF DATA

A. Choice of Boats Using Gill Nets, Lamparas or Purse Seines.

Gill nets, lamparas, and purse seines, all caught white sea bass at San Pedro from 1918 to 1925. By 1925 the purse seine fishermen practically ceased fishing white sea bass because they could not find enough fish to pay for the trips. The cessation of purse seine fishing eliminated that class of boats as a source of data for this investigation.

B. Data Taken from Boats Using Gill Nets.

Data for the analysis were taken from boats using gill nets because they brought in more catches per year of white sea bass than did the lampara boats. Gill nets are designed to entangle individual fish of a limited size range. When a fish of the right size encounters the net its head slips through, and because the body is too large to follow, the fish tries to back out but is held by its gill covers which slip over the webbing. A fish too large will not be caught as its head will not enter the webbing, and the body of one too small will slip through, enabling the fish to escape. As white sea bass gill nets are designed to catch ten to thirty-pound fish, very few other species are caught in these nets. Yellowtail and rock bass are the only other species of any value taken with white sea bass, and these in small quantities. Fishermen, using gill nets, are limited therefore to white sea bass and must fish consistently to make their gear pay. The boats using lampara nets are not so limited since these nets are designed to encircle and impound and are able to catch fish of various sizes and species. Their yearly catch is of many different species which result in fewer white sea bass catches.

IV. DESCRIPTION OF GEAR AND FISHING METHODS

A. Boats.

Two sizes of gill net boats, 24 to 26 feet and 36 to 40 feet in length, are used in the San Pedro fishery. Both sizes were represented in the data used for this investigation. The smaller boats do not have the capacity to carry iced fish below decks, and as a result they must deliver their catch to the market each day. Boats in the larger group can carry from two to six tons of iced fish below deck, and by carrying ice, they can remain at sea seven or eight days before delivering the catch to the markets.

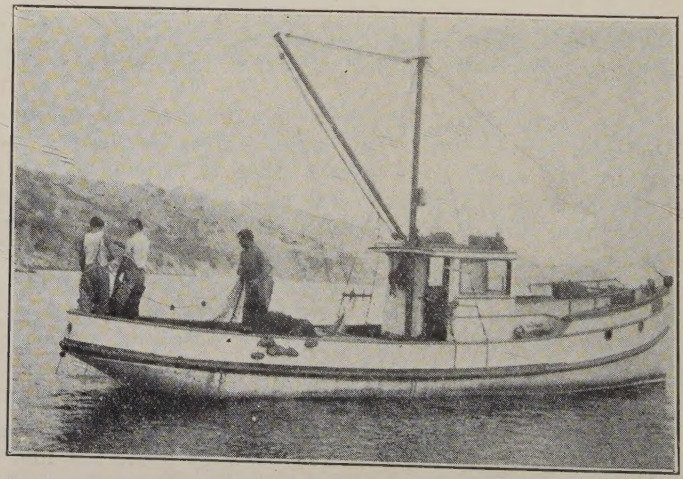

FIG. 4. The *Amelia*, a white sea bass gill net boat of the larger type, owned by Battista Falcone. July, 1929. Photo by Geo. Roger Chute.

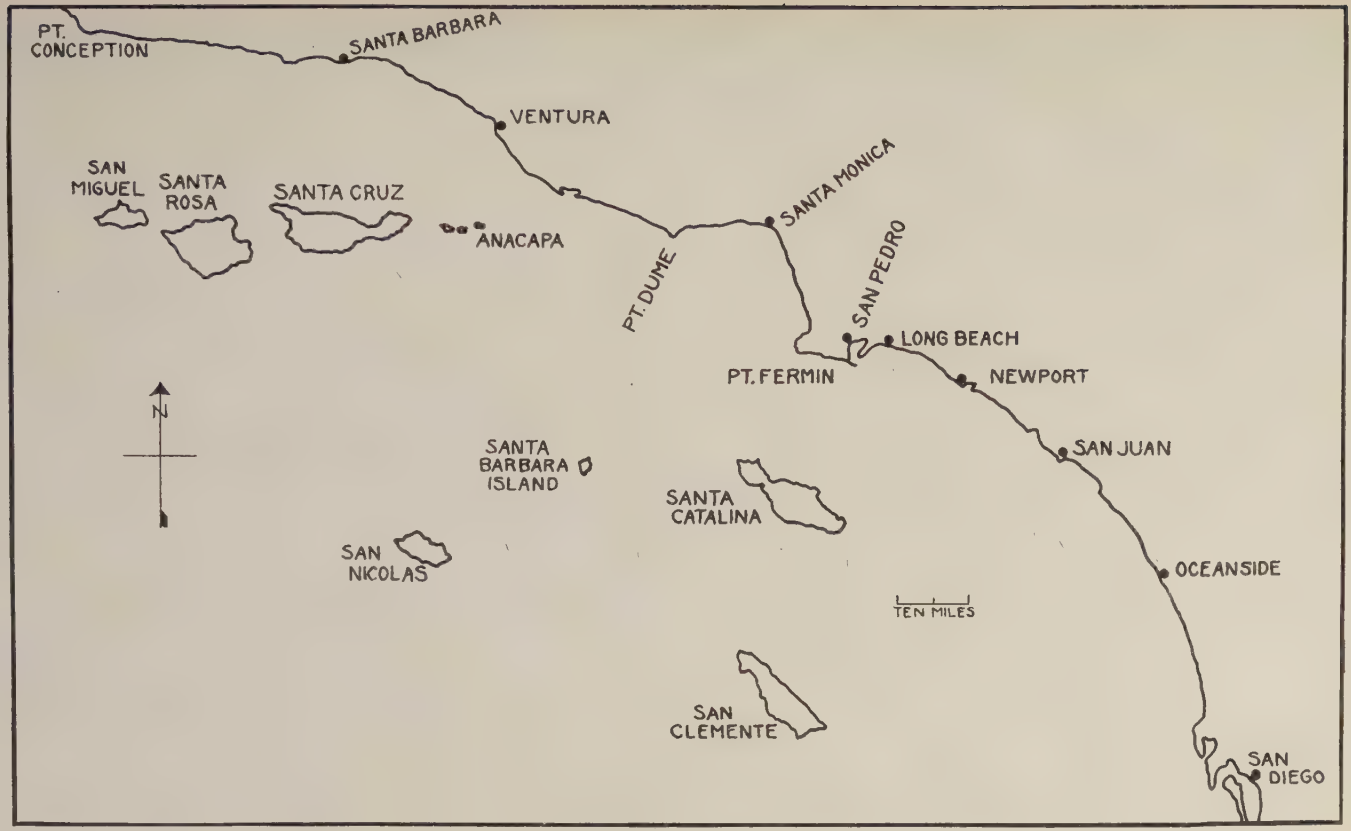

FIG. 5. Map showing fishing localities of the San Pedro white sea bass boats.

B. Nets.

A typical white sea bass gill net is 150 feet long and 21 feet deep (25 fathoms by 3½ fathoms), but there are variations in length from 90 to 180 feet (15 to 30 fathoms), and in depth from 18 to 30 feet (3 to 5 fathoms). Most of the nets have a 7- or 7½-inch mesh, though some vary from 6¾ to 8 inches, and the size of mesh is uniform throughout each net. There has been little modification in the size or construction of the gill nets since 1918. While the smaller boats have used about the same number of nets per boat (10 to 14) each year during the 1918-1928 period, the larger boats have increased the number of nets used per boat from 10 to 15 nets in 1918 to 20 to 35 nets in 1928.

C. Seasons and Locality of the Fishing Grounds.

San Pedro boats fish up the coast of the mainland to Santa Barbara and down to Oceanside and around the islands of Catalina, San Clemente, Santa Cruz, etc. (See Fig. 5.) In the early part of the season, April to August, the best fishing is around the islands. After the first of August, it is generally better along the coast of the mainland. Fishermen say that when sea bass are abundant, catches can be made

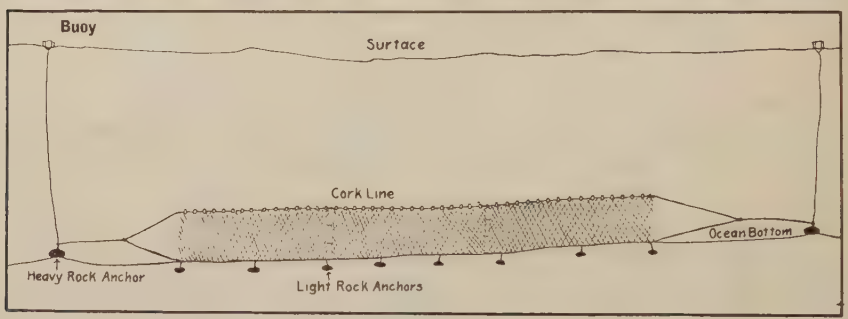

FIG. 6. Sketch (not drawn to scale) shows the construction and setting of a "gang" of white sea bass gill nets on the ocean bottom.

along the coast or around the islands regardless of the season. Although the main season is from May to the end of September, there are a few scattered catches made in March and April.

D. Methods of Fishing.

Fishermen go to the grounds where they think the fish will be the most abundant. Former experiences or the success of other fishermen influence them in their choice of fishing grounds. Two to five nets are joined together into one "gang" and fished as a unit. In 1918, one and two nets were used as a "gang," while in 1928 three to five nets were operated. The gangs are set on the ocean bottom in the kelp near the shore, with a 60- to 70-pound rock or a 20-pound anchor attached to each end of the gang. A buoy, attached with a long line to each anchor or rock, floats at the surface and enables the gang to be easily located. Each net or piece of the gang also has two or three 5- to 10-pound rocks fastened to the lead line on the bottom of the net. If these rocks are not used, 250 lead sinkers (12 to the pound) per net are necessary. These weights keep the lead line in place on the bottom while enough corks are placed on the opposite side of the net

(cork line) to give the net sufficient buoyancy to remain perpendicular to the ocean bottom. (See Fig. 6.) The gangs are set in the kelp parallel to it and in the direction of the tidal current. (See Fig. 7.) They are also taken up in the direction of the tide at the time of lifting. Setting and lifting with the direction of the tide makes it easier to avert catching the nets in submerged rocks.

The nets are lifted once a day and are reset on the same grounds if enough fish are caught. If the grounds are not too far from San Pedro, the boats will leave the nets set and deliver the fish to market, returning in time to lift the nets next day. When the distance to San Pedro is too great, the boats stay on the fishing grounds, lift the nets once a day, and put the catch on ice. The boats either stay out until they catch a load of fish or the ice melts before they return to market the fish at San Pedro. From 1918 to 1920 the boats fished close enough to San Pedro to land their catches each day. After 1920, the larger boats started to take ice and go farther from San Pedro, staying out more than a day, until in 1928 some of the boats remained at sea seven or eight days.

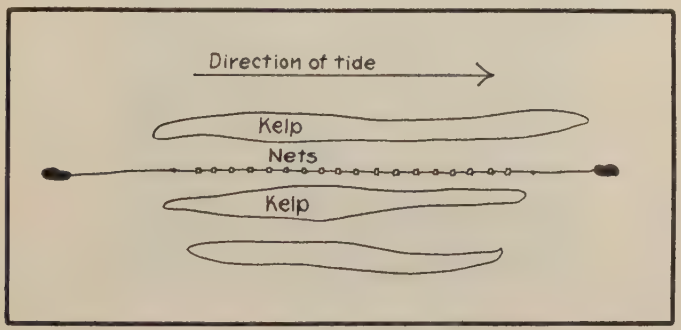

Fig. 7. Sketch (not drawn to scale) shows the position of a "gang" with relation to the direction of the tide and kelp.

E. Cleaned and Uncleaned Fish.

Sometimes the fishermen cleaned the fish (removed the viscera and gills but not the head) before delivering them to port, while at other times they did not. When the fish were cleaned, the loss of weight due to cleaning was about 20 per cent of the uncleaned weight. For cleaned fish, the fishermen received about one-half to four cents a pound (depending on the price at time of delivery) above the uncleaned price. The fish buyer commonly failed to record on the pink tickets whether or not cleaned or uncleaned fish were purchased. When the cleaned fish were not designated as such it was impossible to determine the condition in which the fish were sold, as the fish delivered uncleaned were not often noted either. The correction then for the loss in weight due to cleaning can not be made for a great many of the catches. After going over the prices on the individual tickets each year, the author felt it safe to assume that the proportion of cleaned to uncleaned fish has been constant from year to year. As a result no correction for loss of weight was made on any of the records for cleaned fish.

FIG. 8. Setting the white sea bass gill nets. The boat moves along at about a quarter speed. September, 1929. Photo by S. S. Whitehead.

FIG. 9. Lifting the gill nets. The entangled white sea bass is typical of the way the fish become enmeshed. September, 1929. Photo by S. S. Whitehead.

F. Average Number of Trips Per Month.

The small boats have made consistently more trips per month than the large boats as shown by figure 10. While the drop in the number of trips per month over the period 1918-1928, was 40 per cent for the small boats, the drop for the large boats over the same period was 58 per cent. The straight lines (solid line for the small boats and broken for the large) were fitted to the averages by the method of least squares to show the general trend for each class of boats. The filled-in circles are the points for the averages of the small boats and the unfilled circles for the large boats.

In order to show the actual rate of change between the years, the semi-logarithmic scale was used. The horizontal scale for the years is plotted arithmetically and the vertical scale is plotted logarithmetically. By using the logarithmic scale the difference between five and ten trips is as great as the difference between ten and twenty trips.

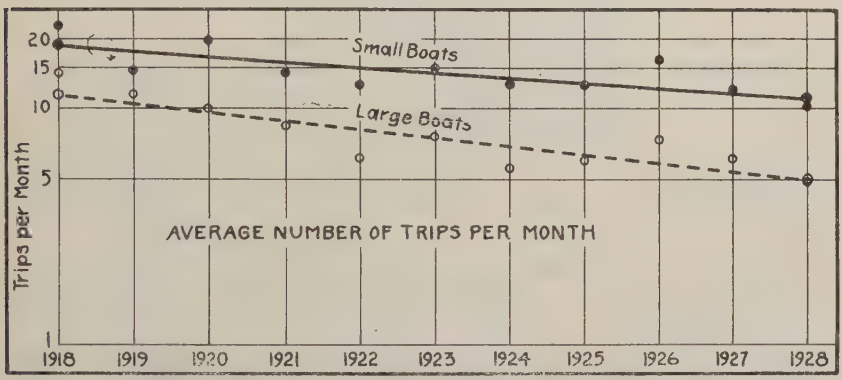

FIG. 10. Dots denote the average number of trips per month for the small boats and the circles denote the averages for the large boats. The straight lines (solid for the small boats and broken for the large) were fitted to the averages by the method of least squares. Semi-logarithmic scale was used.

The natural numbers of the logarithms instead of the logarithms appear on the figure.

G. Summary of Changes of Fishing Methods and Gear.

1. Increase of number of nets per boat, especially in the larger boats.

2. The larger boats stayed out more days per trip each year since 1920.

V. LIMITATIONS OF THE AVAILABLE DATA

A. Time Covered by the Investigation.

The period of investigation started with 1918 as the statistical system of gathering boat catch data was inaugurated then; and the period ended with 1928, the last year for which data were available when the investigation started. Prior to 1918, no data were collected from which the individual boat catches, either catch per trip or catch per month, could be calculated.

B. Only Fourteen Usable Boats Fished During the Period 1918 to 1928.

By going through the registration cards [1] and by questioning fishermen, the maximum number of gill net boats that could be used were selected. There were many boats that may have used lamparas at times. These doubtful boats were discarded in order to be certain that all the boats in the investigation used gill nets only. As a result fourteen boats were all that the author was certain of being strictly gill net boats. Of the fourteen boats selected, only three fished consistently from 1918 to 1927 or 1928. Figure 11 shows the years that the different boats fished. Because of the uncertainty of differentiating the

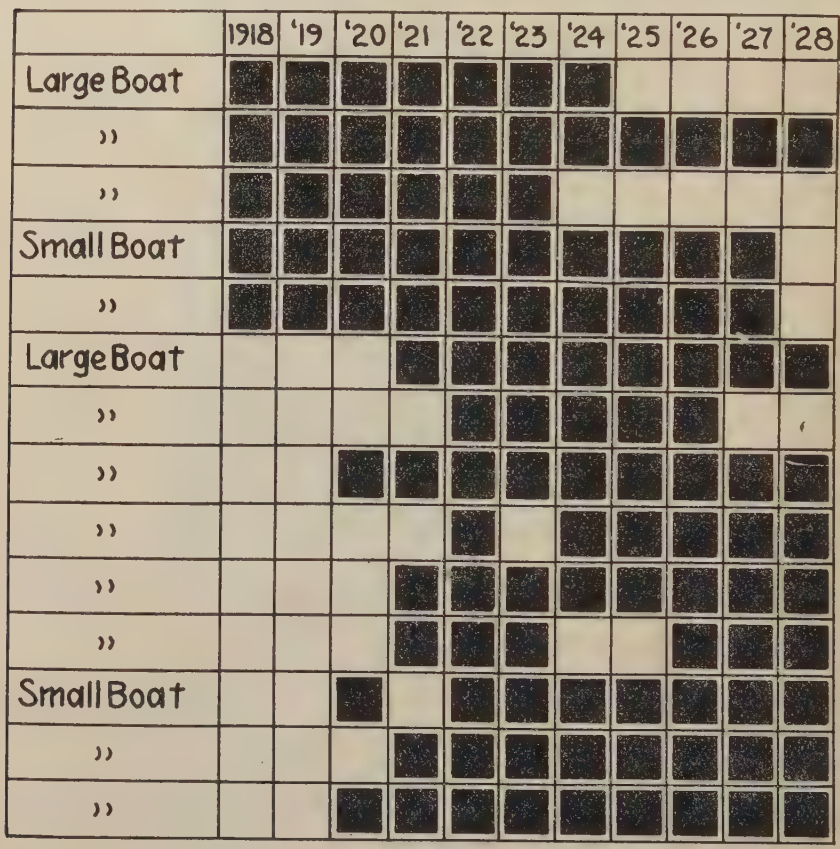

FIG. 11. Black squares indicate the years in which the boats fished.

strictly gill net boats from those using both gill nets and lamparas, the exact proportion of gill net boats to the total number of boats engaged in the fishery is unobtainable. A rough idea of the proportion may be secured by dividing the total number of boats (see table 1) by the number of gill net boats each year. (See Fig. 11.)

[1] Every boat owner operating a boat for profit is required by law to file each year with the Division of Fish and Game of California, on a form furnished by the state, a statement giving the dimensions of the fishing boat, together with the motive power, number of men in the crew, equipment and a complete description of fishing gear (size and amount used).

Ideal data would be from a great number of boats fishing over the entire period with a constant amount of effort. The data available from the white sea bass fishery are not ideal. Besides having only three boats that fished consistently over ten years or more, the unit of effort per trip has changed. (See summary of changes of gear and fishing methods, on page 13.) More gill nets per boat were used in 1928 than in 1918, and the larger boats in recent years have stayed out fishing more than one day. If the fishery were in a healthy condition, this added effort would make for an increased average catch per trip. On the other hand if the trend of the yearly average boat catch per trip determined from the data is downward, the actual decline of the fishery should be more rapid. For example—a boat using ten nets in 1918 and marketing the fish every day had an average catch per trip of one hundred pounds. In 1928 the same boat using twenty nets and marketing every four days had an average catch per trip of eighty pounds. The boat in 1928 used twice as many nets, and as a result the catch per trip should be divided by two in order to reduce the 1928 trips to the same amount of effort of gear as the 1918 trips (average catch of forty pounds). In 1928 the boat fished four times longer per trip than in 1918, the catch per trip should be further reduced by dividing by four days (average of ten pounds). Ten pounds per trip is the return for the 1928 trips based on the same amount of effort as the 1918 trips. The drops from 1918 to 1928, when no correction was made for the increased effort, was 20 per cent, while the drop when the increased effort was discounted was 90 per cent.

C. Number of Days per Trip of Large Boats Not Constant.

Boat catch per trip is an accurate criterion only when the number of fishing days per trip (amount of time the gear is fishing) has remained constant from year to year. When the number has not remained so, the amount caught per trip might have little significance as an index of condition of the fishery. If in 1918, five hundred pounds were caught in one day, while in 1928 five hundred pounds was the product of five fishing days, in 1928 five times more effort was expended than in 1918. The amount per trip was the same in both years but if the 1928 trip were reduced to the same effort as the 1918 trip, only one hundred pounds could be credited to 1928. If in each trip the author knew the number of days actually spent in fishing, each trip could be reduced to a basis of effort that would be comparable from year to year. As the amount and price of the species landed on a certain date is the only information derived from the pink tickets, the time actually spent in fishing can not be differentiated from the time spent in port. Because the effort expended each trip is not known, the amount caught per trip can not be reduced to a base that would be comparable from year to year.

When sea bass could be caught close to San Pedro, the boats landed the catch of fish every day, but after 1921 the fishing was poor around San Pedro and the boats have gone to more distant grounds. These extended trips have been more prevalent among the larger boats as they could carry enough ice and fish to pay for a long trip. Because the small boats could not carry sufficient ice and fish, they have been limited to Catalina Island and on the mainland from Newport to Santa Monica. (See Fig. 5.) The larger boats go from Point Dume on the

mainland and Santa Cruz, Santa Rosa, San Clemente or San Nicolas islands, and by carrying ice are able to remain on those fishing grounds seven or eight days before delivering their catch to the markets at San Pedro. From 1918 to 1920 practically all of the trips were of one day's duration, but after 1920 the boats started to make a practice of staying away more than one day.

D. Possible Inadequacies of Data from Small Boats.

The small boats seem to furnish the most reliable data. They have landed their catches nearly every day, and have not increased the number of nets per boat appreciably. Figure 12 is a graph of the average boat catch per trip of the small and large boats. The total amount caught each year was divided by the total number of trips made in each year. For the small boats, the drop from 1918 to 1921 was very rapid, while from 1922 on, the drop lessened. A rapid decline at first and then a gradual drop after the fishery had declined to a relatively low point may be typical of a fishery suffering from depletion. On the

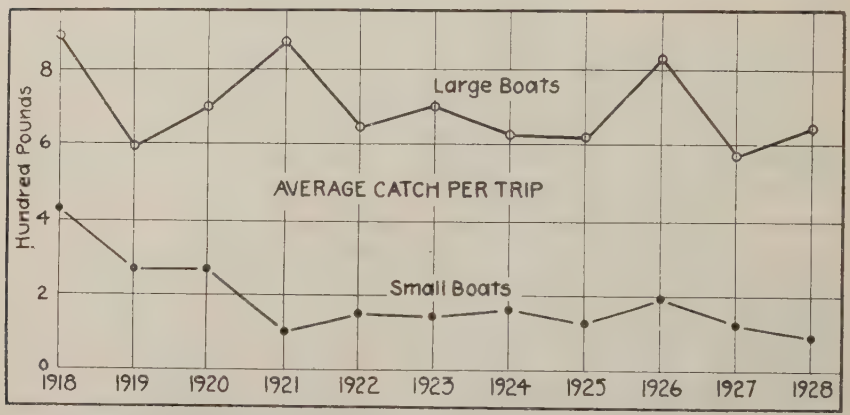

Fig. 12. Average boat catch per trip of the small and large gill net boats.

other hand the shape of the trend may be due to the inadequate data. The plotted points for the small boats for 1918 and 1919 were the averages of two boats, 1920 and 1921 four boats, and for the rest of the years five boats, except 1928 which was from three boats.

Average boat catch per trip determined from data of the large boats is open to two errors. The fishermen have increased the number of fishing days per trip each year, and also increased the number of nets per boat. These two changes mean an increased amount of fishing effort each year, which should be discounted in order that the catch per trip may reflect the fishing success for each year.

VI. USE OF CATCH PER MONTH DISCOUNTS THE CHANGES IN NUMBER OF FISHING DAYS PER TRIP

Using boat catch per month as an index discounts the changes in the number of fishing days per trip. For example—two boats fished twenty-five days in a month and both boats caught the same amount of fish each day. One boat brought its catch to market every day and the

other boat every fifth day. The catch per trip of the boat that marketed its catch every five days was five times greater than the boat that marketed its catch every day, but the monthly catch of the two boats was the same. By discounting the changes in the number of days per trip, the data from the large boats may be used. The information gathered substantiates the premise that catch per month is indicative of the condition of the fishery; that is, a relatively small average catch per month in a year indicates the scarcity of fish for that year.

A. Increased Demand for White Sea Bass.

Demand for white sea bass certainly has not decreased since 1921 as shown by the average annual prices paid to the fishermen. (See Fig. 13.) The drop in 1921 and 1922 was probably due to the economic postwar slump which was common in all of our fisheries. As the price of white sea bass increased steadily since 1922 the fishermen have had the incentive of a high price to make catches of white sea bass.

B. Constant Attempts of Fishermen to Catch White Sea Bass.

An examination of the pink tickets of the gill net fishermen indicates that once the boats started fishing sea bass in a season, they fished them to the exclusion of other species. Fishermen say that they have

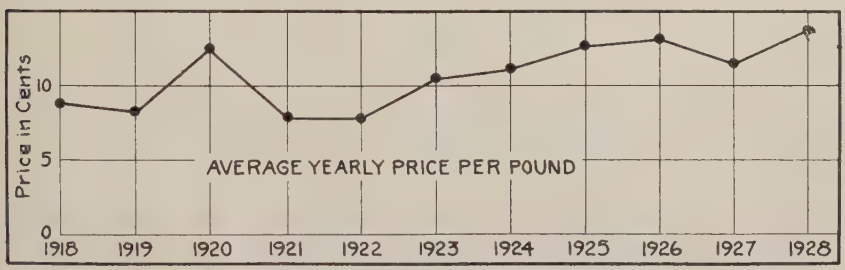

Fig. 13. Average annual prices paid to the fishermen.

made a constant attempt to get sea bass each year, and that they have not spent more time in port in recent years but have put in more days per trip.

VII. AVERAGE CATCH PER MONTH

A. Average Boat Catch Per Month for All the Boats Used.

The average monthly boat catch was calculated for the fourteen boats by the following method. Deliveries resulting from the trips for each boat and each year were tabulated from May through September. Catches before May and after September were discarded because of their infrequency. The amount caught each month was ascertained for each boat over the period that it fished. The monthly boat catches for all the boats in each year were summed and divided by the number of months entering into the sum. These simple arithmetic averages (for the years 1918 to 1928) are produced graphically in figure 14.

B. Possible Inaccuracies of the Above Method and Means of Eliminating Some of Them.

1. *Grouping the boats.* The above method is open to many possible inaccuracies. Only three of the boats used, fished ten years or more of the period 1918 to 1928, while the rest either stopped early in the

period or started in later. Figure 11 shows the years that the fourteen boats fished. If the average boat catch per month were taken for each of the boats as they start fishing in the period, the resultant averages may be inaccurate. For example—a boat new to the group starting to fish in 1922, with a larger amount of gear than the other boats, may give a false increase for that year. In order to eliminate this, the boats were divided into two groups so that all of the boats in each group start fishing in the same year. One group is made up of five boats that operated from 1918 to 1924 (group 1) and the other of twelve boats that fished from 1922 to 1928 (group 2). Catches of boats that fished in years not included in the two groups were discarded. The three boats that fished over the entire period 1918 to 1927 or 1928 were included in both groups (1918–1924 for group 1, and 1922–1928 for group 2). Each group was treated separately until the average monthly catch was computed, then the two groups were combined in a manner which will be described later.

The catch per trip for each boat and year was tabulated, and the amount caught for each month and the number of trips were ascertained for each boat over the period that it fished.

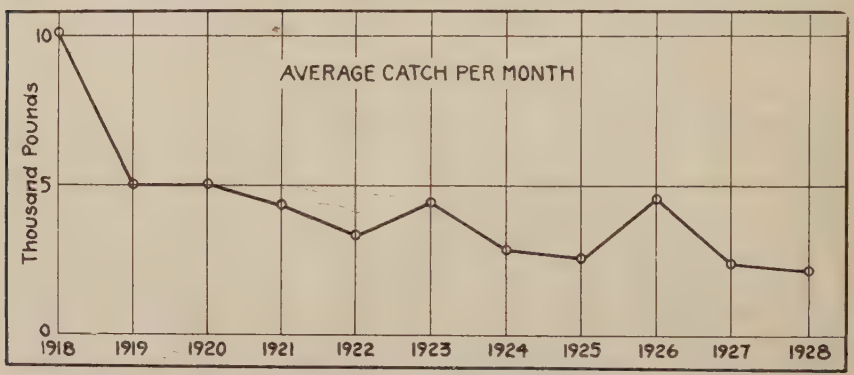

Fig. 14. Average boat catch per month for the fourteen gill net boats.

2. *Weighting monthly catch by the number of trips.* Each monthly catch was multiplied by the number of trips in that month. Few trips may have been made in a month because of engine trouble, sickness, etc., and not because of fishing conditions. By multiplying the monthly catch by the number of trips, the month with the greatest number of trips was given the most weight in determining the average for the year. The product of the monthly catches for each boat and the number of trips made in that month were added for each year and divided by the total number of trips. This gave a weighted monthly average for each boat and year.

3. *Monthly catches raised to the same base.* The average monthly boat catches (as determined above) of some of the boats were consistently higher than those of others. If the monthly catches were used in this manner to compute the monthly averages for all the boats, the boats with large monthly catches would have too much weight in determining the final average catch for the group. Boats with small monthly catches should reflect the condition of the fishery as well as boats with large monthly catches.

In order to give the boats making consistently low monthly catches equal weight with boats making large catches, the average monthly boat catches of each separate group were raised to an equal basis. An average monthly catch of each boat over the period that it fished was determined. Then the boat that had the largest catches in each group was used as a base. This largest average monthly boat catch was divided by the average monthly catch of each of the other boats in their respective groups. These results indicated the amounts by which the monthly catches of each boat should be multiplied, to put all the boats on the same base. When the monthly catch of each boat was multiplied by its respective factor, the monthly catches of each boat had the same mean and equal weight in determining the final average for its group.

4. *Determining the average monthly catch of the two groups for each year.* All the monthly catches (as determined on page 18, "Weighting monthly catches by number of trips") for all the boats in each separate group were summed for each year and divided by the total number of trips the boats in their respective groups made. The average monthly boat catch thus determined represents the relative

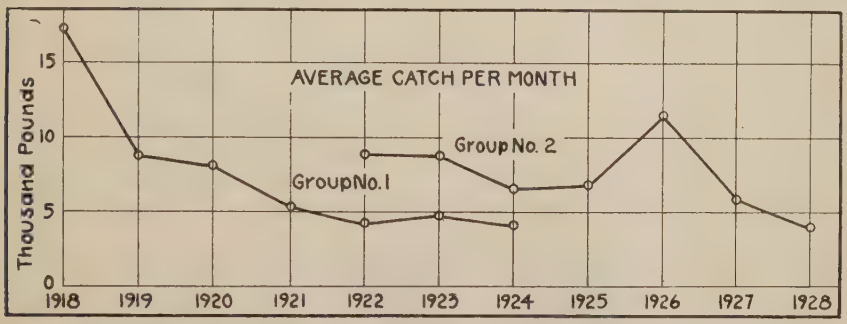

FIG. 15. Average boat catch per month of boats fishing during period 1918–1924 (group 1) and of boats fishing during period 1922–1928 (group 2).

fishing success for each group and each year. These are presented in graphic form in figure 15. It should be remembered that the two groups are made up of different boats which explains the fact that the two trends do not coincide from 1922 to 1924. The majority of the boats that entered into group 2 carried more nets and were bigger boats, thus making consistently larger catches than those of group 1.

5. *Combining the two groups.* As the rate that the average monthly boat catch increased from year to year is important and not the actual amounts of this increase or decrease, the two trends may be easily combined. A drop from four thousand to two thousand pounds is as significant as a drop from thirty thousand to fifteen thousand pounds over the same length of time. In each case the second amount is one-half of the first.

In order that the amounts for the two groups may form a continuous trend, group 1 was raised to conform with group 2. The average monthly boat catches for each group of the three years 1922 to 1924, were averaged. Then the 1922 to 1924 average of group 2 was divided by the 1922 to 1924 average of group 1 to determine the factor necessary to raise group 1 to the same base as group 2. When the average

monthly boat catches of group 1 were multiplied by the factor, groups 1 and 2 formed a continuous trend. Because the two groups overlapped from 1922 to 1924, the points for these years were the average of the two groups. The average monthly boat catch for each group and year (1922 to 1924) was multiplied by the number of monthly catches which made up the average for its respective group. These products were summed for each year and divided by the total number of months. The influence each group had on the final average from 1922 to 1924 was decided by the number of months comprising the average.

Figure 16 is the result of the combination and is plotted on a semi-logarithmic scale. The trend of the average monthly boat catches is

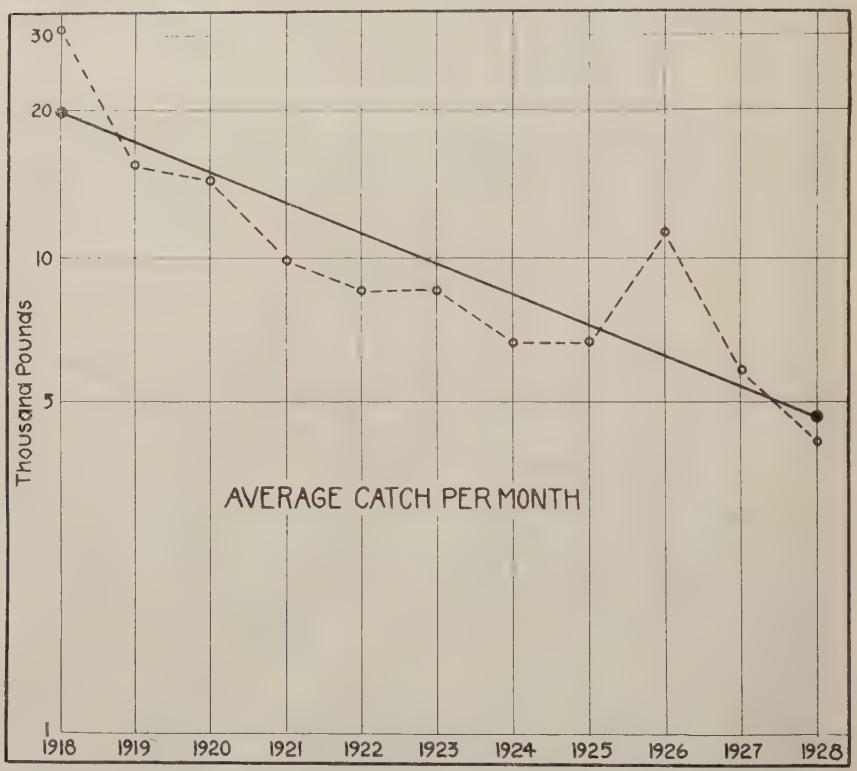

FIG. 16. The light line is the trend of the average boat catch per month in which the boats were grouped and the monthly catches weighted by the number of trips, then raised to the basis of the boat making the largest catches. The line that best fits (heavy line) the averages was calculated by the method of least squares. Semi-logarithmic scale was used.

steadily downward, dropping from thirty thousand in 1918 to four thousand pounds in 1928. With the exception of 1926 each year is lower than the preceding year, which indicates that the fishermen received less return for their effort each succeeding year. There are bound to be yearly fluctuations such as a particularly suitable spawning season which will result in an abundance of fish being available to the fishermen when the fish reach commercial size. The low points in 1927 and 1928 indicate that the conditions causing the high point in 1926 were temporary.

6. *Straight line fitted to the averages.* A straight line that will best fit the yearly averages should show the general condition of the fishery as it smooths out the yearly fluctuations. Such a line was fitted by the method of least squares and is presented by the heavy straight line in figure 16. This line indicates a decided decline from practically twenty thousand pounds in 1918 to forty-six hundred pounds in 1928, or that fishing in 1918 was over four times better than in 1928. The reader should remember that these averages do not represent actual catches, but have been raised to a comparable base of the boat making the largest catches.

The actual decline in the fishery was no doubt greater than the data indicate. Catch per month has not discounted all the increased effort

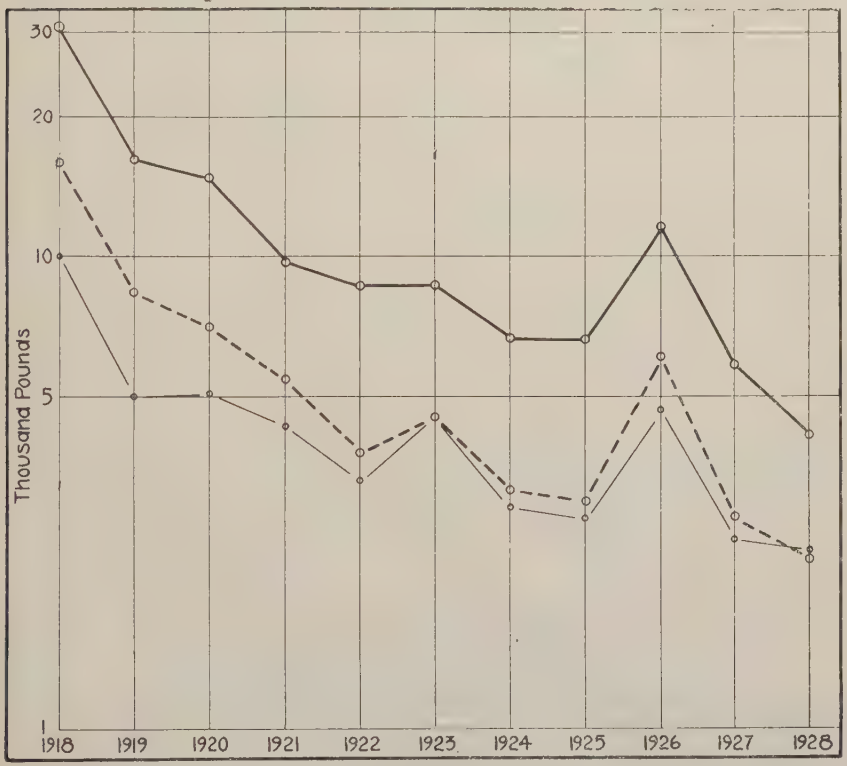

Fig. 17. Average boat catch per month. The heavy solid line is the trend of averages in which the boats were grouped, monthly catches weighted by the number of trips and raised to the basis of the boat making the largest catches. The heavy broken line represents the trend of the averages when the boats were grouped, and the monthly catches weighted by the number of trips. The light line is the trend of the simple arithmetic averages of the monthly catches of the fourteen boats.

each year. Increase in effort resulting from the yearly increase in number of nets per boat can not be discounted as the data for the actual number of nets used by each boat are not available. This inaccuracy will be present under existing conditions in any method in which the data from the large boats are used.

C. Comparison of Different Methods of Computing Average Monthly Catches.

Figure 17 presents a comparison of the different methods of determining the average monthly boat catches. A method which has not

been described is to be used in this comparison. This method is the one in which the monthly catches are weighted by the number of trips, and the boats are divided into two groups so that all the boats in each group start fishing the same year. The only difference between this method and the method for determining the averages for the data of figure 16 is that the monthly catches of boats in each group have not not been raised to the base of the boat making the largest monthly catches in its respective group. These averages are represented by the heavy broken line in figure 17.

The heavy line represents the data of figure 16 in which the monthly catches have been weighted by the number of trips made in that month; the boats grouped in order that all the boats in each group start fishing at the same year, and all monthly catches raised to the base of the boat making the largest catches in each respective group.

The method of taking the sum of the monthly catches in each year and dividing by the number of months is presented by the light line (data of figure 14). This method does not weight the monthly catches

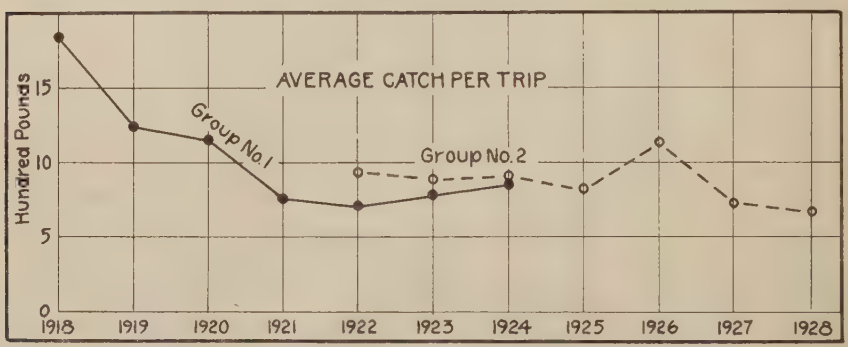

FIG. 18. Average boat catch per trip of boats fishing during 1918–1924 (group 1) and of the boats fishing during 1922–1928 (group 2).

by the number of trips in a month, and it does not group the boats nor raise the catches to the same base.

There is little difference in the results of any of the three methods. The reason for the heavy line being higher than the other two is that its catches have been raised to the basis of the boat making the largest catches while the catches of the other two methods were used in their natural state.

Straight lines fitted to the heavy solid and broken lines would have the same downward slopes. The probable error of each year's average would no doubt be large, due to the small number of monthly catches and the wide range of variation among them. If the probable errors were computed for each year's average as shown by the heavy line, they would be large enough to include the difference between these averages and those indicated by the broken line. The writer did not consider probable errors of sufficient importance to compensate for the task of computing which would be great, due to the system of weighting used in determining the monthly averages.

A straight line fitted to the light line in figure 17 would have less of a slope than the other two lines. This was due to the relatively low average for the first three years. These relatively low averages were

caused by the false averages after 1921, which were due to the influx of different boats making bigger catches. By the grouping of the boats in the other two methods, these false high averages were eliminated through the raising of average monthly catches of group 1 to conform with those of group 2.

Each of the three methods indicated a pronounced decrease in the average monthly boat catch which signifies that the white sea bass are becoming less available to the fishermen.

VIII. COMPARISON OF CATCH PER TRIP WITH CATCH PER MONTH

A comparison of the method using average boat catch per month with that using average boat catch per trip is of interest to show the

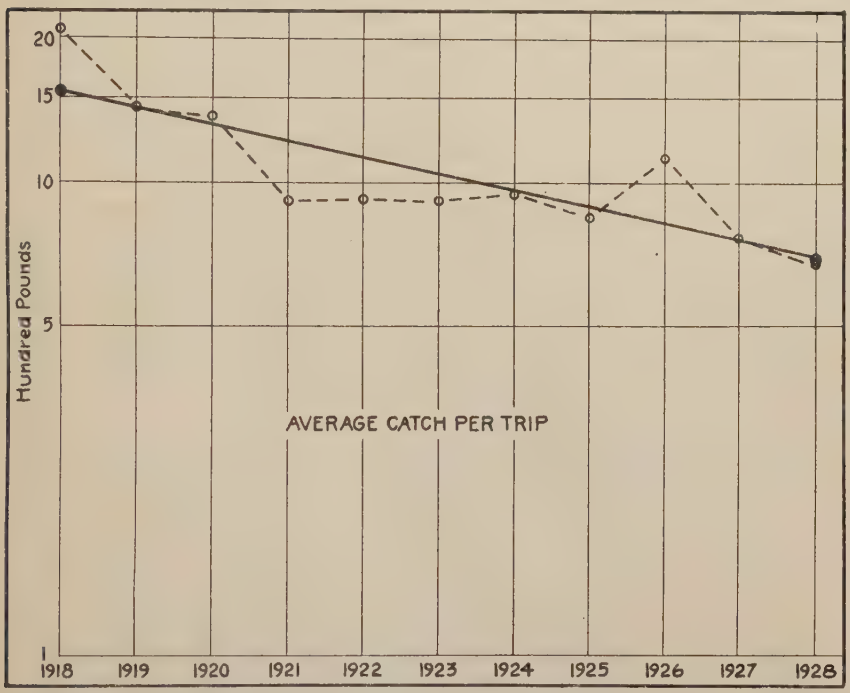

FIG. 19. The light line is the trend of average boat catch per trip in which the boats were grouped and the trip catches were raised to the basis of the boat making the largest catches. The straight line was fitted by the method of least squares. Semi-logarithmic scale was used.

effect of the longer trips on catch per trip. The average boat catch per trip was computed in a manner to make it comparable with the average boat catch per month (data of figure 16).

A. Method of Computing Catch per Trip.

The boats were divided into two groups so that all the boats in each group started fishing at the same time. As the amount caught each trip had already been tabulated, the average catch per trip for each group was determined by dividing the yearly catch of the boat by the number of trips the boat made that year. Each boat's average catch was raised to the same base in order that the catch per trip of all the boats would

have the same mean. After the average catch per trip of all the boats had been multiplied by their respective factors, summed for that year, then divided by the corresponding number of trips, the result was the average catch per trip for each group. Figure 18 is the graphic presentation of the average catch per trip of the two groups. The group of 1918 to 1924 (group 1) was raised to form a continuous trend with the group of 1922 to 1928 (group 2) by the same method as was used for figure 16. This trend is shown by figure 19. The dotted line shows the actual averages, while the heavy straight line, fitted to the data by the method of least squares, indicates the general trend. From 1918 to 1921 the drop of the dotted line is very abrupt while from

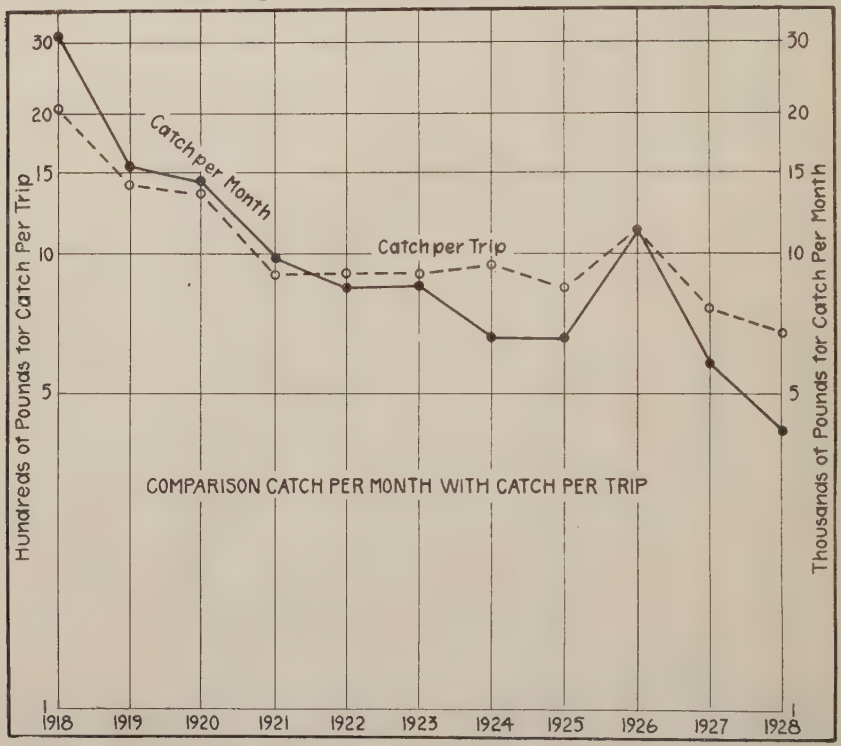

FIG. 20. Comparison of average boat catch per month with average boat catch per trip. Solid line average boat catch per month, and broken line average boat catch per trip.

1921 on, the drop is relatively slight. The average catch per trip was kept up after 1921 by the fishermen exerting more effort per trip. This added effort consisted in the fishermen's staying out more days per trip and using more nets per boat.

B. Plotting the Two Methods on a Comparable Scale.

Figure 20 shows the comparison of catch per trip with catch per month in which the yearly increase of number of days per trip were discounted in the latter method. The catch per month averages were about ten times greater than the catch per trip averages. In order to make the two trends comparable the pounds per trip were plotted on a scale ten times greater than that of the pounds per month. Both of

the trends dropped at about the same rate until 1922 and from then on the drop of catch per month greatly exceeded that of catch per trip. This difference in the drop of the two trends was due to the fishermen's staying out fishing longer which kept up the catch per trip, but not the catch per month.

IX. ERROR CAUSED BY INCREASED NUMBER OF NETS PER BOAT

To discount the error of increased nets per boat, the catch per net is necessary. In order to determine the catch per net, the exact number of nets the boats used each year is needed, but this is impossible to procure as the fishermen can not remember how many nets they used in past years, and the number of nets the boats used have not been noted every year on the boat registration cards. All that the fishermen remember is roughly the number of nets they used around 1918, and accurately for 1927 and 1928. The number of nets the small boats used was ten to fourteen in 1918 to 1928, while the large boats used ten to fifteen in 1918 and twenty to thirty-five in 1928. As a result the error of increased nets per boat will be present in any method of boat catch analysis when the existing data from the large boats are used.

X. CATCH PER MONTH BEST CRITERION UNDER EXISTING CONDITIONS

The error of increased number of nets is common to both catch per month and catch per trip. Increased number of fishing days per trip is discounted by catch per month and not by catch per trip. Catch per month comes the nearest to reflecting the true condition of the fishery. As a result, the method of using catch per month as a criterion is the best under the existing conditions. (See Fig. 16.)

XI. EVIDENCES OF DEPLETION

The trend of average boat catch per month is decidedly downward during the period 1918 to 1928. Since the two trends, average boat catch per month and average boat catch per trip (see Fig. 20), are decidedly downward, we can safely assume that the availability of white sea bass to the fishermen has decreased each year during the period. Unless the sea bass have changed their habitat over the period studied, a decrease in availability to the fishermen means depletion.

The period 1918 to 1928 may be part of the downward trend of a fluctuation of abundance over a long period of years. For example—the herring of Europe has had long periods of scarcity followed by long periods of increasing abundance, etc. If something like this were true of the white sea bass fishery, it would need much protection when the population reached the low point, otherwise it might not rise again but be reduced to commercial extinction.

White sea bass on the other hand may have been depleted due to a series of adverse spawning seasons or an increase of natural enemies. If the fishery were depleted because of these conditions, it needs added protection from man's fishing in order to regain its strength.

If the depletion were due to overfishing, which is very likely the case, it should be remedied by protecting the fishery against further depletion due to man's overfishing.

In any case no matter what the causes of depletion may have been, the white sea bass fishery needs protection in order to insure it against extinction in the future.

XII. SUMMARY

In the white sea bass fishery it has been found that:

1. Total catch and average boat catch per year are not suitable criteria of the conditions of the fishery.
2. Gill net boats furnish better data than the lampara boats.
3. Catch per month is a better index than catch per trip.
4. Both catch per month and catch per trip indicate a pronounced depletion of the white sea bass fishery.
5. Since depletion is evident, the white sea bass needs protective legislation.

CALIFORNIA DIVISION OF FISH AND GAME

FISH BULLETINS

* No. 1. Report on Fish Conditions. 1913; 48 pp., 3 figs. Contains:
The Abalone Industry in California. By Charles Lincoln Edwards.
The Towing of Salmon and Steelhead Fry from Sacramento to the Sea in a "Live Car." By N. B. Scofield.
The Problem of the Spiny Lobster. By Bennet M. Allen.
Investigation of the Clams of California. By Harold Heath.
Investigation of the Life History of the Edible Crab (*Cancer magister*). By F. W. Weymouth.
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* No. 2. The Scientific Investigation of Marine Fisheries as Related to the Work of the Fish and Game Commission in Southern California. By Will F. Thompson. 1919; 27 pp., 4 figs.

* No. 3. The Spawning of the Grunion (*Leuresthes tenuis*). By Will F. Thompson, assisted by Julia Bell Thompson. July 15, 1919; 29 pp., 9 figs.

No. 4. The Edible Clams, Mussels and Scallops of California. By Frank W. Weymouth. Jan. 10, 1921; 74 pp., 19 pls., 26 figs.

* No. 5. A Key to the Families of Marine Fishes of the West Coast. By Edwin C. Starks. March 3, 1921; 16 pp., 4 figs.

* No. 6. A History of California Shore Whaling. By Edwin C. Starks, October 1922; 38 pp., 22 figs.

* No. 7. The Life History and Growth of the Pismo Clam. By Frank W. Weymouth. 1923; 120 pp., 15 figs., 18 graphs.

* No. 8. Racial and Seasonal Variation in the Pacific Herring, California Sardine and California Anchovy. By Carl L. Hubbs. February, 1925; 23 pp., 4 pls.

* No. 9. Preliminary Investigation of the Purse Seine Industry of Southern California. By Tage Skogsberg. 1925; 95 pp., 23 figs.

* No. 10. The Life History of *Leuresthes tenuis*, an Atherine Fish with Tide Controlled Spawning Habits. By Frances N. Clark. October, 1925; 51 pp., 6 graphs, 7 pls.

No. 11. The California Sardine. By the Staff of the California State Fisheries Laboratory. 1926; 221 pp., 74 figs.
I. Thompson, Will F. The California Sardine and the Study of the Available Supply.
II. Sette, Oscar Elton. Sampling the California Sardine: A Study of the Adequacy of Various Systems at Monterey.
III. Higgins, Elmer H. A Study of Fluctuations in the Sardine Fishery at San Pedro.
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